APPLICATION OF RELIABILITY IMPROVEMENT WARRANTY (RIW) TO DOD PROCUREMENTS

Dennis Jean Allen

NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

APPLICATION OF RELIABILITY IMPROVEMENT WARRANTY (RIW) TO DOD PROCUREMENTS

by

Dennis Jean Allen

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Thesis Advisor: R. R. Judson

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with the use of Reliability Improvement Warranties (RIW's) has led to the conclusion that the RIW may be a valuable tool in bringing buyer/seller goals into agreement by transferring the management of costs to the seller. Background material on DoD and commercial warranty experience is used to form the framework for an evaluation criteria developed by ARINC Research Corporation to test the applicability of RIW to a particular acquisition. The limited DoD guidance which has been promulgated is recapitulated for consolidation with the ARINC criteria and recent experience.

Application of Reliability Improvement

Warranty (RIW) to DoD Procurements

by

Dennis Jean Allen
Lieutenant, Supply Corps, United States Navy
B.S., California State College Long Beach, 1966

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requirements for the degree of

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ABSTRACT

The existence of a goal conflict in the buyer/seller relationship is inherent under a profit motivated system where conventional procurement techniques are used. The buyer seeks maximum performance at minimum life cycle cost and the seller seeks to maximize profit which may translate to minimizing reliability improvement costs. Experience of military and commercial procurement activities with the use of Reliability Improvement Warranties (RIW's) has led to the conclusion that the RIW may be a valuable tool in bringing buyer/seller goals into agreement by transferring the management of costs to the seller. Background material on DoD and commercial warranty experience is used to form the framework for an evaluation criteria developed by ARINC Research Corporation to test the applicability of RIW to a particular acquisition. The limited DoD guidance which has been promulgated is recapitulated for consolidation with the ARINC criteria and recent experience.

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I. INTRODUCTION

Contractor motivation in the procurement process has been historically perceived as profit oriented. Consequently, most contract incentives have been linked to profit as an inducement for the contractor to seek the objectives established by the buyer. Recent analysis of contractors participating in DoD procurements has resulted in the conclusion that profit alone may not be the dominant objective of most contractors [Ref. 1]. Maximization of such factors as cash flow, sales, market share, or return on investment, may be viewed as more realistic objectives. In addition to these financially oriented goals, the contractor may seek a long term relationship with the buyer which could involve short term financial losses or minimum profit. With the buyer's goal being maximum performance at minimum life cycle cost and the seller pursuing a goal which does not consider all of the costs to be born by the buyer, rather, only the production cost; there exists a goal conflict in the buyer/seller relationship.

Motivation of the contractor toward the objectives of the buyer has been the purpose of incentive contracts which are in wide use today; however, if these contracts are incentivizing the wrong factors the conflict will remain unresolved. Rather than analyzing each contract situation (assuming objectives change from one contract to another for

any one contractor) to determine what factors to incentivize, it is infinitely more productive to create a contract where the seller may pursue his own goals in arriving at completion; but, at the same time he will maximize the objective set out in the buyer's requirement. A mechanism for achieving both buyer and seller goals in the procurement process may be the use of a Failure Free Warranty (FFW) or as it has more recently been called, a Reliability Improvement Warranty (RIW). This thesis will attempt to answer the questions of whether RIW is a viable means of resolving the goal conflict of buyers and sellers and to what extent it is applicable to DoD procurements.

Answering the above questions will require analysis of contractor performance when using a Reliability Improvement Warranty contract. Determination of RIW procurement viability will be possible after performing an analysis of assumed contractor behavior. Applicability of RIW to DoD procurements will be discussed both from the historical perspective as well as through analysis of contractor behavior when performing with or without the provisions of RIW.

II. DEFINITIONS

A. PURPOSE OF WARRANTIES

In defining the terms to be used in this discussion extensive coverage must be given to the word "warranty." The purpose of a warranty is to protect the buyer from unidentifiable defects in the supplies or services provided by the seller and to limit the liability of the seller. The warranty is then the legal link between buyer and seller after the contract is completed or perhaps even while the contract is in progress. In order to provide protection to buyers of goods and services, uniform legal provisions have been enacted by all the states. The Uniform Commercial Code (UCC) which replaced the Uniform Sales Act of 1906 is now recognized as the basis for transacting any public or private contract. Since there is no Federal Law that conflicts with the UCC, the Government has felt free to adopt these codes as the guide for Government contracts. In an Armed Services Board of Contract Appeals (ASBCA) decision in 1964, the Board stated that the UCC has been adopted by 28 states (now, all states) and that the UCC reflects the best in modern decision and discussion. Two types of warranties exist based on the UCC to provide buyer protection.

B. TYPES OF WARRANTIES

The first type of warranty is implied in that the seller is providing merchantable goods which are to be used for a purpose known to both buyer and seller. UCC states that:

> "Where the seller at the time of contracting has reason to know any particular purpose for which the goods are required and that the buyer is relying on the seller's skill or judgment to select or furnish suitable goods, there is, unless excluded or modified under the next section, an implied warranty that the goods shall be fit for such purpose." [Ref. 2, p. 86]

The UCC also provides remedies to the buyer in the event of a breach of an implied warranty which closely resembles the actions available to the government under the fixed price supply inspection clause. These actions include recovery of excess purchase costs and reimbursement for incidental and consequential charges.

In government procurements the existence of an implied warranty depends on the type of contract. In cost-reimbursement contracts, the implied warranty does not apply. Fixed-price construction contracts may take advantage of implied warranties, but in fixed-price contracts for supplies and services the inspection clause is a conclusive acceptance and it invalidates any implied warranty [Ref. 3, p. 8715].

The second type of warranty is an express warranty which may be conveyed by affirmation of fact, description of the goods to be bought, or conformance of delivered material to the specifications of a model or sample. UCC 2-313 further states that:

> "It is not necessary to the creation of an express warranty that the seller use formal words such as 'warranty' or 'guarantee' or that he have a specific intention to make a warranty, but an affirmation merely of the value of the goods or a statement purporting to be merely the seller's opinion or commendation of the goods does not create a warranty" [Ref. 2, pp. 79-80]

C. ASPR DEFINITIONS

Although the Armed Services Procurement Regulations (ASPR) do not define an express warranty, ASPR 1-324 does state that a warranty does provide the government with the contractual right to assert claims regarding the deficiency of supplies or services. The decision to use a warranty is reserved for the Chief of the Purchasing Office emphasizing the fact that warranties must be used only if economically feasible and administratively practical. Of specific concern to the present discussion of RIW application in DoD procurements is the list of factors in Appendix A which must be considered in deciding whether to use a warranty clause.

ASPR defines five types of express warranties. They are:

Supply warranty - requires the contractor to replace or reperform work on contract items found to be defective at the time of acceptance.

Correction of Deficiency Warranty - requires the contractor to correct design, material or workmanship deficiency which is found to exist during test and evaluation or early operation so that the equipment meets the specification.

Service Warranty - specifies a time period during which the contractor agrees to reperform defective services, providing defects in workmanship existed at the time of acceptance and are discovered during the period.

Construction warranty - requires the contractor to remedy, at his own expense, any nonconformance of work to the contract specifications and any defect in design, material or workmanship.

Reliability Improvement Warranty - places complete responsibility on the contractor for repair of defects for a specified period of time or a measured amount of operation and may require demonstration of performance improvement over the life of the contract.

It is the last of these warranty categories which will receive further investigation as to its applications and limitations.

D. VARIATIONS OF RIW

Variations of the RIW exist which may incorporate any number of areas relating to the performance of the equipment purchased. These areas include (a) Mean Time Between Failure (MTBF), (b) Mean Time To Repair (MTTR), (c) False Removal Rate (FRR), (d) Direct Maintenance Manhours (DMMH), (e) Elapsed Maintenance Time (EMT), (f) Beyond Capability of Maintenance (BCM) Rate, (g) Not Operationally Ready Supply (NORS) Rate, (h) Availability, and (j) Turn-around Time (TAT). Although the practicality and cost of administration of these types may vary, it is possible to construct a contract

which will affect contractor consideration of any one or all of these characteristics and be based on demonstrated performance in the warranty area.

E. ACHIEVEMENT OF SYSTEM EFFECTIVENESS

As a baseline for entry into any procurement the buyer must have in mind some measure of effectiveness against which to judge the hardware which is delivered. In subsystem and component acquisitions this measure of effectiveness has generally been reliability expressed as mean time between failure (MTBF). Rarely has there been an effort made to take a systems approach to the acquisition process and as a consequence the specification of reliability for subsystems and components has not been a cost effective process. The interdependence of subsystems mandates the need for an integrated systems approach to the specification of reliability. Optimization of subsystem cost and reliability parameters would provide the desired level of probability of completing the mission at minimum cost. The Air Force Systems Command has shown that it is possible to determine optimum levels of subsystem reliability for a major weapon system even though cost data may not be refined to point estimates [Ref. 4].

It is essential that consideration be given to the level of reliability desired for each subsystem regardless of the procurement technique to be employed. Figure 1a illustrates this point qualitatively for the relationship of reliability versus the research, development and production cost to be incurred to achieve any given level of reliability. The

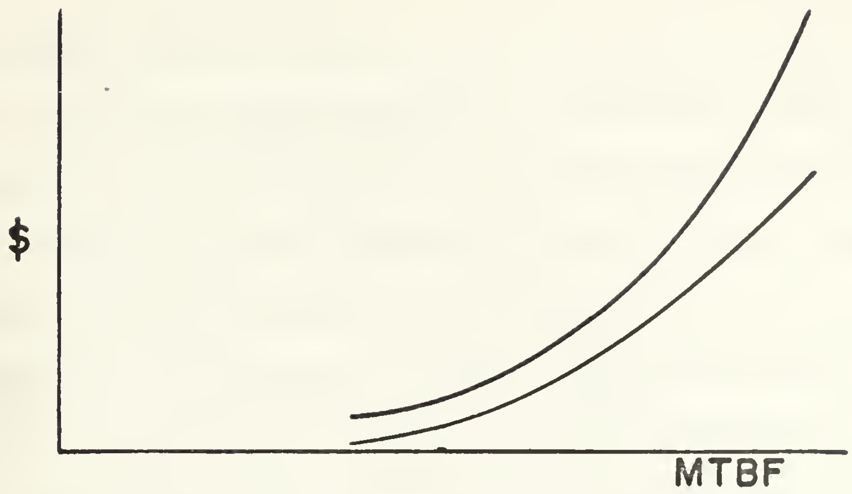

Figure Ia Cost of Reliability Improvement

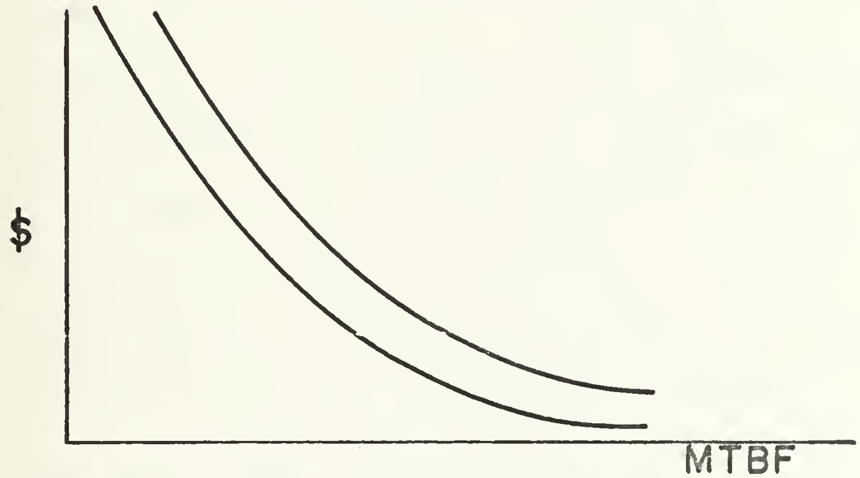

Figure Ib System Operation and Maintenance Cost

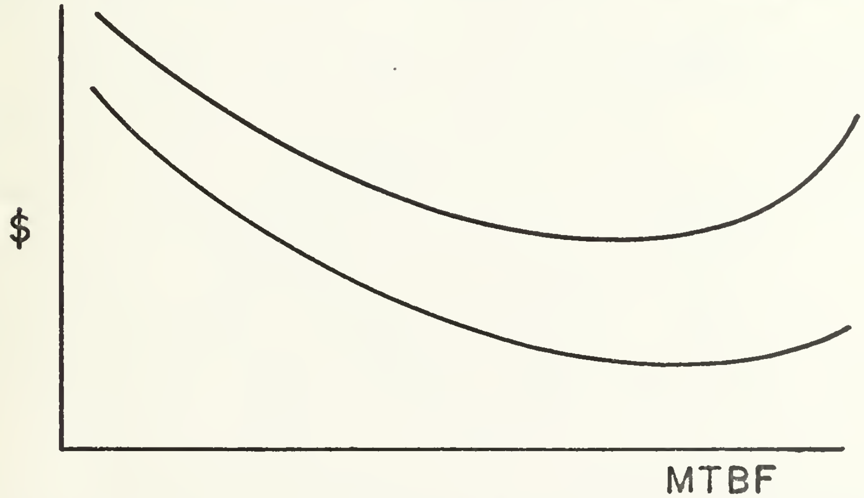

Figure Ic System Life Cycle Support Cost

Figure I DEVELOPMENT OF SYSTEM LIFE CYCLE SUPPORT COST

vertical width of the curve at any given point represents the uncertainty associated with achieving that level of reliability. The life cycle cost considerations for a subsystem, however, also include the operation and maintenance (O&M) cost of the item and these O&M costs are depicted in Figure 1b in relation to MTBF. Total life cycle support costs are derived by adding the two previous curves as represented by Figure 1c. The development of the relationship of subsystem life cycle support costs to achieve various levels of reliability and the relationship of subsystem reliability to the probability of the system completing its mission will provide the basis for cost effectiveness trade-offs in the design and evolution of the system. Although a systems approach to system reliability requirements is not mandatory for any one particular procurement technique, it is easy to see the possible consequences in increased costs of over-specifying subsystem reliability.

One additional comment should be made at this point concerning requirements for reliability. In the discussion to follow concerning commercial airline practices and experiences with warranties the concept of form, fit and function specifications is brought forward. Basically, this concept considers the area between input and output of a component or system to be the concern of the manufacturer and not the buyer. The airlines give to competitive suppliers a set of characteristics which describe the form of the component, i.e. visible panel requirements, connector and receptacle

locations. The fit characteristics describe location and dimensions, and the function characteristics define all mechanical, electrical, and visual inputs or outputs. The use of this type of requirement in military procurements appears to have merit and is under study in a procurement presently in progress which will be discussed later.

F. SELLER MOTIVATION

A qualitative comparison of warranty and non-warranty procurement techniques may be undertaken after establishing with some degree of confidence the shape of the curves in Figures 1a and 1b. The standard procurement approach recognizes the importance that the frequency of equipment failure and the expense involved in equipment repair are prime determinants of support costs. Therefore, a specified minimum level of reliability based on the relationship between support cost and reliability is demanded in the contract. Incorporation of a RIW with an MTBF guarantee in the procurement forces the contractor to view the outcome of his effort in a slightly different light.

The buyer believes that in a standard procurement reliability is controlled by the specification of a minimum acceptable level. In fact, however, it is the contractor who controls the reliability that is built into the equipment. Demonstrated reliability will depend largely upon how sharply the contractor concentrates on it during design, development, and production. If the contractor's basic motivation is one of profit the situation exists as is illustrated in Figure 2.

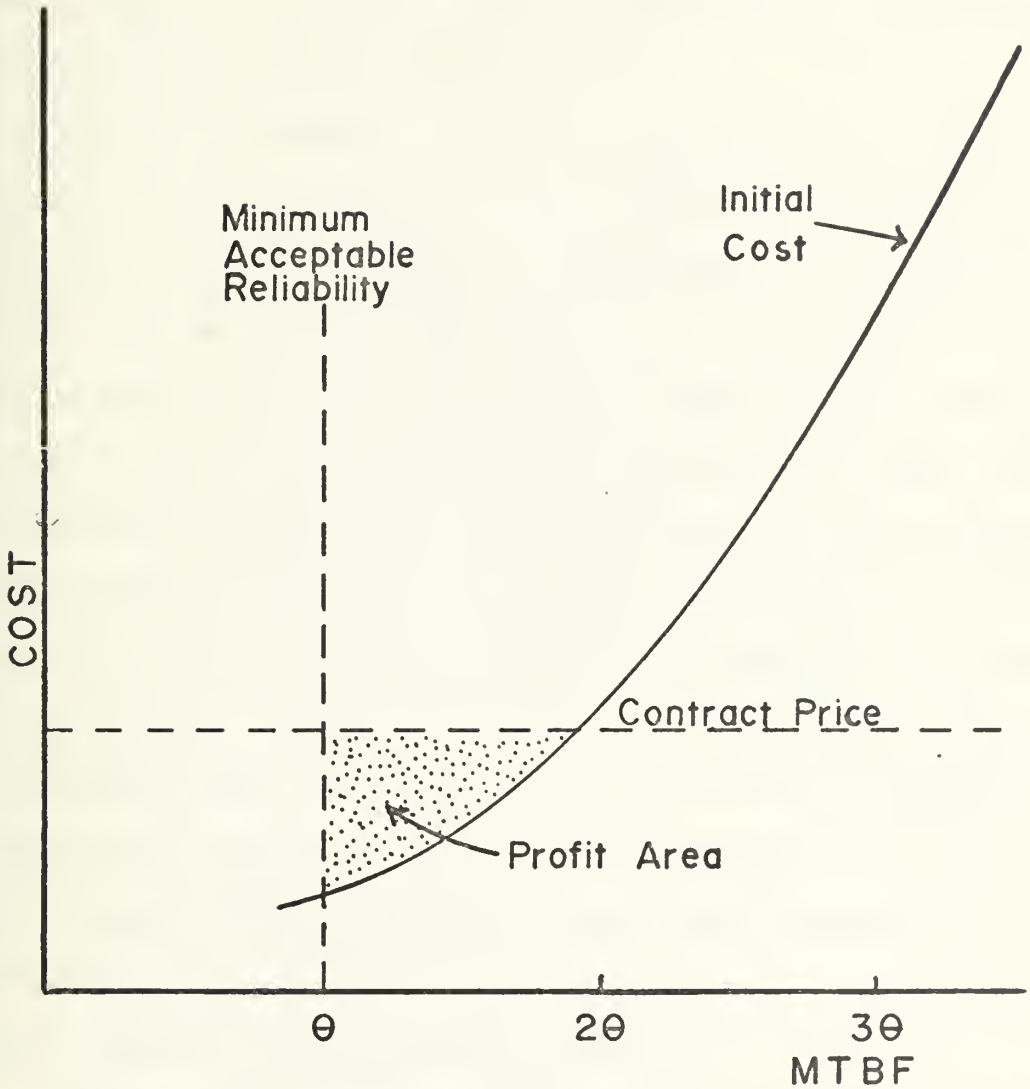

Figure 2 EFFECT OF RELIABILITY ON INITIAL COST

The general relationship between initial equipment cost (research, development, and production) and reliability produces an area of profit identified by the shaded segment. No particular significance need be associated with the precise shape of the curve, but it does indicate increasing cost associated with higher reliability. With an agreed upon contract price the supplier will seek to maximize the difference between price and cost.

While the minimum acceptable reliability places a limitation on how far down the curve the contractor may go, in practice tests to demonstrate achievement of the required level are not yet as unequivocal as tests of other equipment parameters, such as, power output. Reliability demonstration is also time consuming and expensive and there can be considerable debate about the number of failures experienced. Additionally the criteria for what constitutes a failure may be difficult to establish. Two basic problems face the buyer using conventional procurement techniques. First, the contractor, who alone can raise the levels of equipment characteristics that are basic determinants of support costs, is economically motivated to lower them.[7] Second, the lack of definitiveness of the demonstration test creates uncertainty about the actual achievement.

Incorporation of a RIW with MTBF guarantee in the production contract requires the same analysis as a conventional procurement to arrive at a minimum acceptable level of reliability. In this contract the supplier is asked to quote a

price for the desired equipment and a price for which all repairs will be made for the duration of the contract. In formulating the equipment design and proposal the contractor views reliability and support costs in a new light. Over-estimation of the expected reliability will affect the supplier's cost of repair in the fixed price environment of the contract. Provided the award is competitive the potential suppliers will be disinclined to underestimate the achievable reliability in order to improve profit since that action may result in loss of the contract.

The management of the life cycle costs in a RIW contract is transferred to the supplier. The supplier's cost/reliability curve takes the shape of Figure 3 and trade-offs can be made at the supplier's discretion. It should be noted that the shape of the supplier's cost curve is, in essence, the same as that previously perceived by the buyer and that the buyer's cost is represented by a straight line fixed at the price of the contract. As in the conventional procurement technique it is reasonable to assume that the contractor will seek to maximize profit and move toward the minimum on the curve. During equipment design the contractor can introduce changes which, while resulting in higher initial cost, will be more than compensated for in reduced support costs. In addition, the contractor's concern with reliability improvement does not end with the production phase. Any subsequent modifications that will move total costs to a lower point on the curve will be given serious consideration.

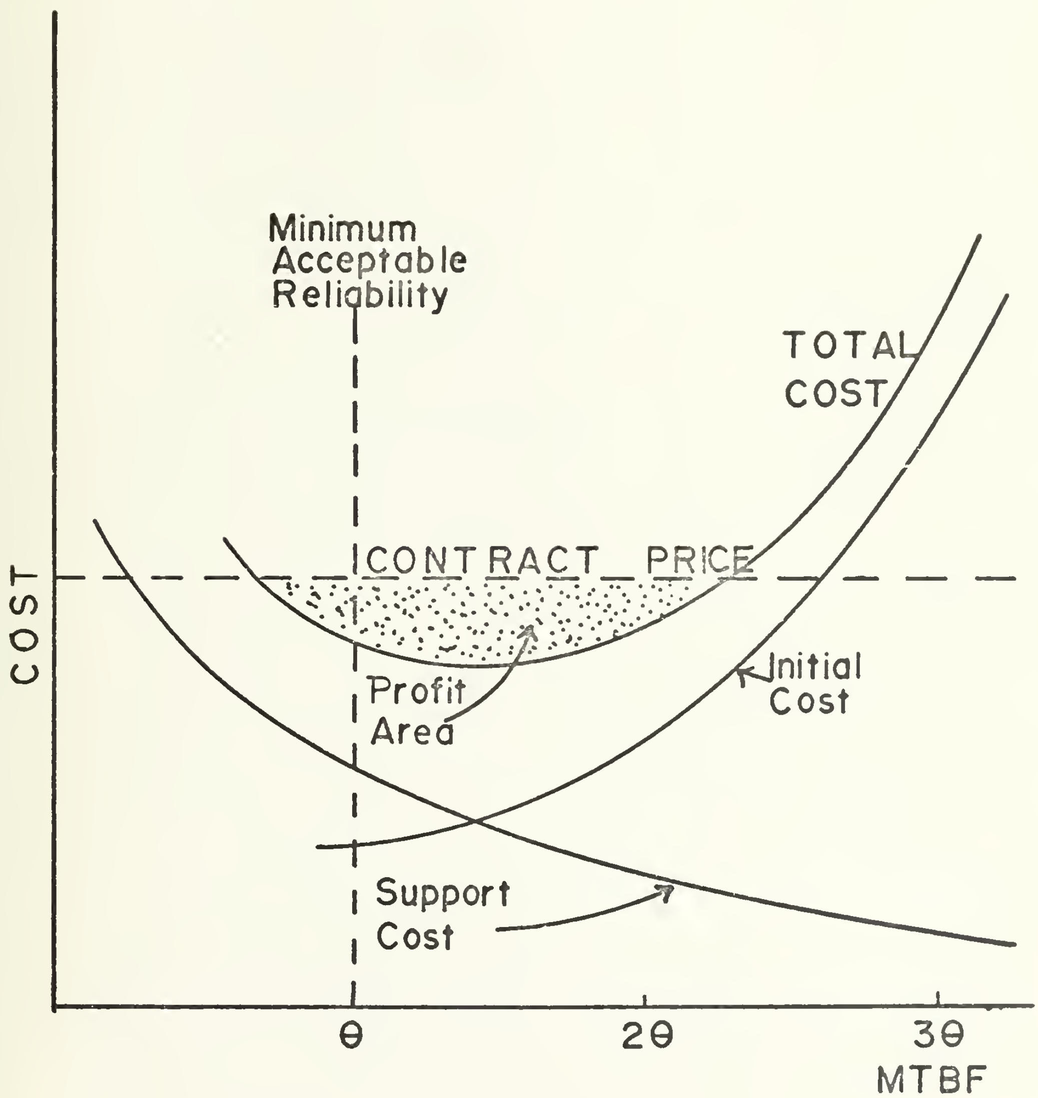

Figure 3: EFFECT OF RELIABILITY ON INITIAL AND SUPPORT COSTS

The warranty provision thus places responsibility for all costs on the supplier and allows the freedom for the supplier to manage those costs.

III. BUYER/SELLER RESTRICTIONS

Aside from the mechanics of supplier motivation and buyer decision-making on reliability requirements, there are restrictions on the use of RIW which may rule out its applicability from the outset. Since the supplier is accepting all of the cost risk in a firm-fixed price RIW contract there must exist a reasonable amount of certainty about the shape of the failure-rate curve of the warranted equipment. The supplier will be able to predict plant loading requirements for repair of the equipment based on the shape of the failure-rate curve.

Some empirical evidence exists for electronic and electromechanical devices which suggests a "bathtub" shaped failure-rate curve as illustrated in Figure 4. Electronic and electromechanical devices lend themselves to warranty application because of the constant failure-rate exhibited after initial burn-in during the infant mortality period. Equipments which do not exhibit wearout characteristics can be said to have a constant failure-rate. As a consequence, any equipment which is as good after some period of use as it was when it was new can be categorized as a candidate for RIW procurement. As an example of an item which demonstrates wearout characteristics consider an automobile or aircraft tire. Each increment of use which is obtained from the tire increases the chance of failure. It is reasonable to assume that a contractor would be hesitant to accept the cost risk

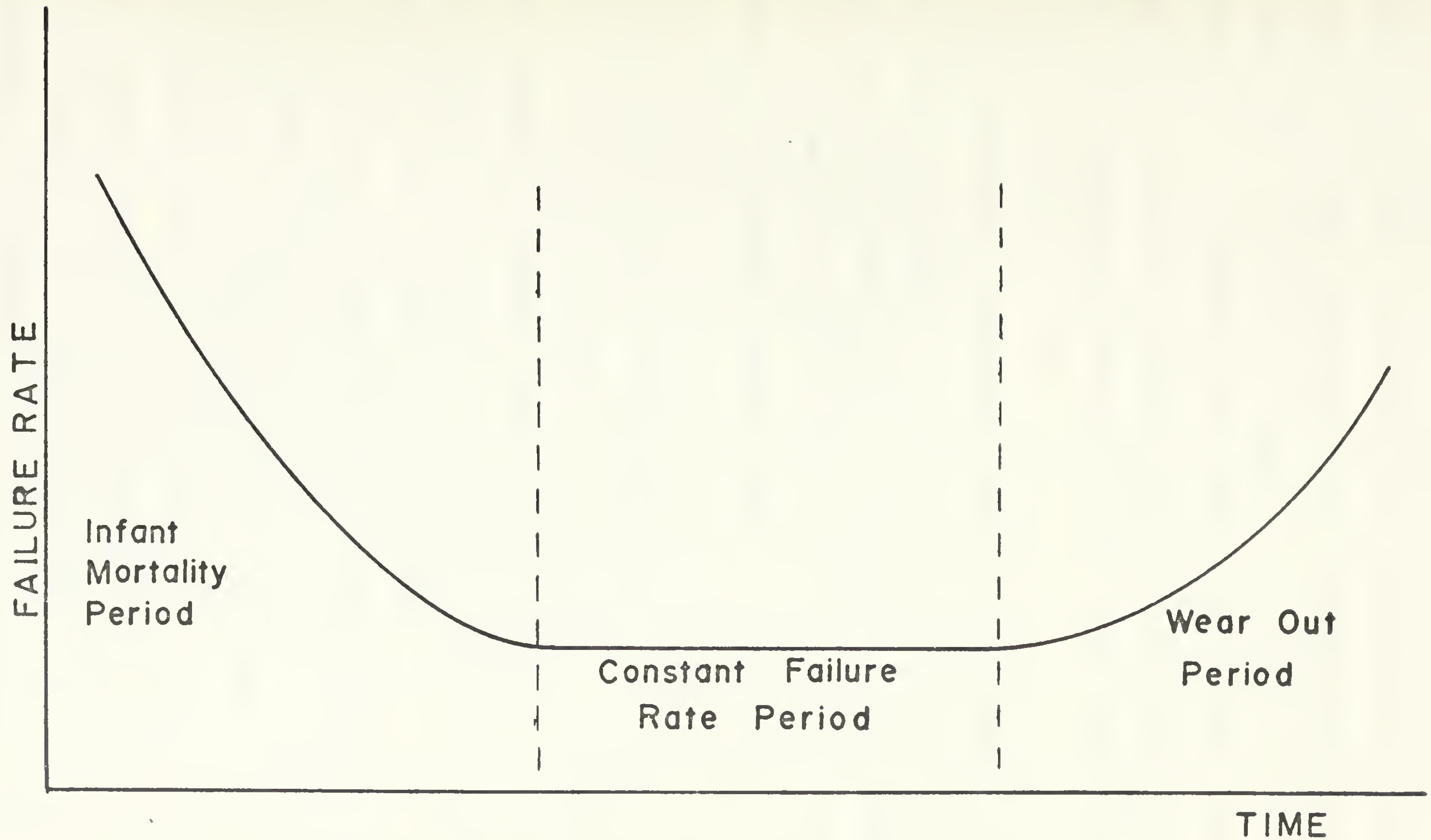

Figure 4 FAILURE RATE CURVE

involved in supporting an equipment which has an increasing failure-rate curve and therefore it is essential for the protection of the contractor that an MTBF guarantee which extends into the wearout phase of the equipment failure-rate curve not be included in the RIW contract. The degree of uncertainty about the shape of the failure-rate curve will affect the supplier's analysis of the cost risk and penalties of the contract.

The contractor performing under a RIW demands that organizational maintenance be limited to a functional check and test capability and preventive maintenance requirements. In some instances the supplier has trained and certified buyer personnel to perform limited repair. Adequacy of preservation and packing facilities at the organizational level must be verified to ensure proper handling of defective components for return to the contractor's facilities. Protection of the contractor against buyer induced damage or "murder" losses must be incorporated into the contract so that the supplier is not liable for those losses.

The buyer is forced to relinquish configuration control of the equipment supported by RIW, but the supplier must maintain form, fit, and function. The essence of the contractor's benefits from a RIW agreement resides in the control of the design of the equipment within form, fit, and function guidelines. How the supplier redesigns and re-engineers the equipment determines what improvements will be demonstrated in reliability and as a consequence what the

supplier's repair costs will be. Redesign can also reduce the supplier's cost of repair by optimizing materials used in repair and labor requirements to affect those repairs.

In order to stimulate contractor interest in making performance/cost trade-offs the warranty should be of sufficient duration to permit the recovery of the contractor's investment in product improvement. The contractor can be expected to make an investment in reliability improvement if the probability of avoidance of future repair costs is sufficiently high to warrant the investment. Allowing the contractor to manage the design and make trade-offs on his own eliminates most of the delay normally encountered in the approval and implementation of an engineering change generated within DoD.

The cash flow realized under a RIW contract has some bearing on the decision-making process by the supplier. The conventional procedure for payment for a RIW contract has been on an annual percentage basis over the life of the contract. A representative cash flow on a five year RIW contract, as viewed by the supplier, is illustrated in Figure 5. Assuming that the component or system is a technical advancement of an existing equipment there will be some product development cost on the minus side of the cash flow graph. The plus side of the graph is essentially fixed by the nature of the contract, i.e. firm-fixed price, and thus the contractor must make trade-offs between production, reliability improvement, and repair costs. There exists a

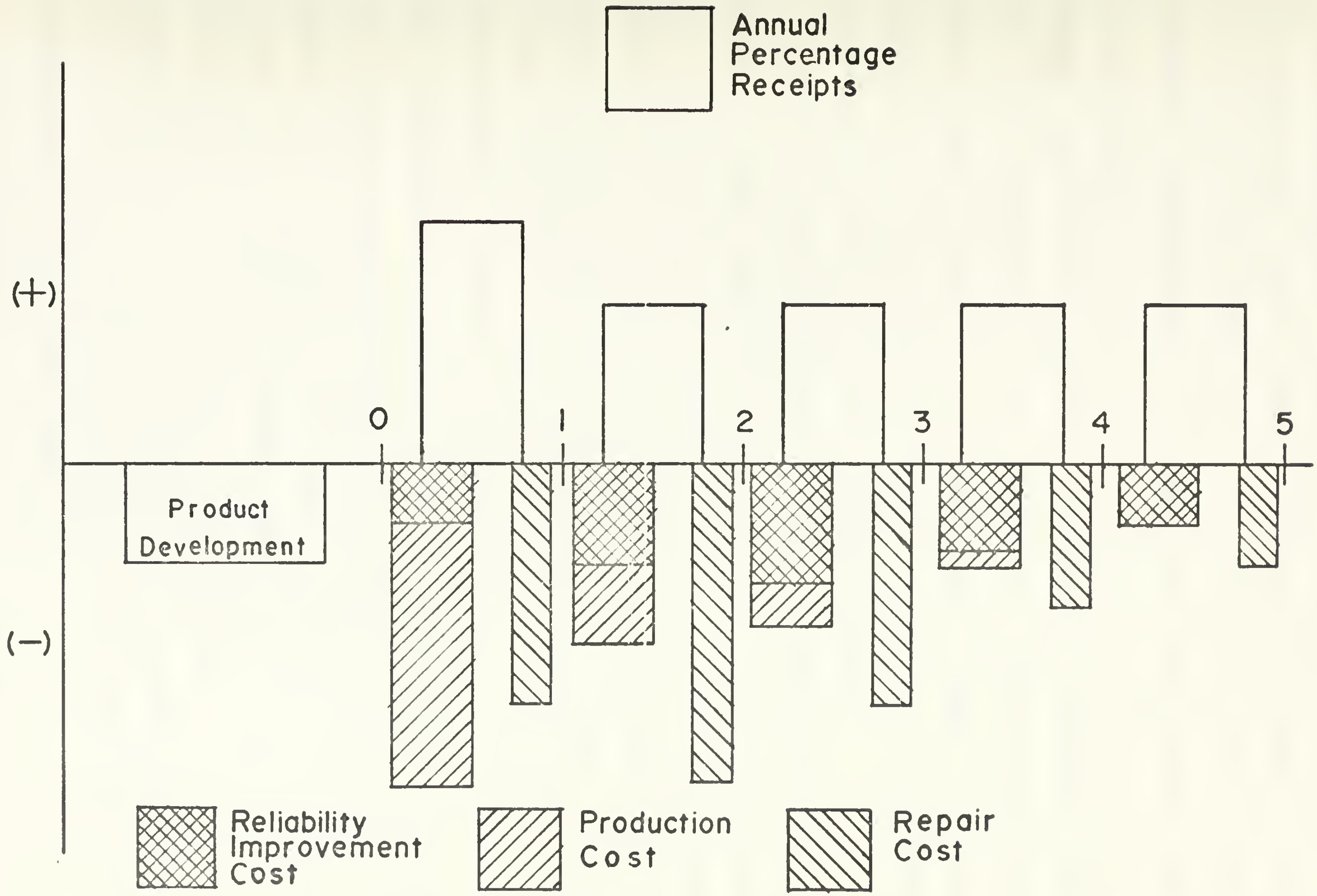

Figure 5: SUPPLIER CASH FLOW FROM RIW CONTRACT

relationship between reliability improvement investment by the contractor and the expected reduction in cost of repair that can be realized from it. In the early stages of the contract the supplier will be more willing to invest capital in improvements to the product. The decision process which takes place can be compared to a standard investment decision with the exception that the contractor knows in advance the market value of whatever decision that is made. The unknown quantity in the calculation that is performed is the cost avoided in repair of the warranted components.

The decreasing likelihood that the contractor will invest capital in a modification which could improve reliability as the contract progresses and the near certainty that improvements will not be made which are not cost effective to the contractor are two weaknesses in the RIW concept. There are provisions available which can strengthen these observed weaknesses. Improvements which are not cost effective for the contractor to include in the equipment can be offered to the buyer at anytime during the contract in the form of Value Engineering proposals. The buyer's evaluation of these proposals will determine the cost benefits to be derived and the value of incorporation in the equipment. This does not suggest that the contractor will have a mechanism for avoiding liability provided the RIW includes an MTBF guarantee which must be met by the supplier.

Buyer restrictions on the use of warranties stem from the buyer's concern with life cycle costs. In analyzing a

proposal for use of RIW the costs avoided from conventional in-house support are relevant. However, the refinement of cost data within the life cycle categories of development, production, and operation proves to be a difficult task. Where the analysis is being performed on equipment presently supported by in-house means, parallel programs of warranty and nonwarranty can be carried on and the data thus collected can be compared. The Lear Siegler AJB-3A two-gyro-stability platform is an example of this type of analysis conducted by the Aviation Supply Office of the Navy.

In the case of a new component being introduced as a sub-system of some larger weapon system, a parallel analysis is not possible and reliance on some form of modeling may be substituted. The development of life cycle cost models has been documented in References 5 and 6 but in each case the requirements for data limit the value of the model. The conclusions derived from the models can only be accepted to the extent that the cost data is accurate. Data collection systems are currently in operation which will bring visibility to specific cost categories necessary to make decisions about the use of warranties (Navy 3M System and Air Force AFM-66-1 System). In the interim, a means must be made available to the buyer to make decisions about the cost effectiveness of warranty use. This interim procedure in the case of DoD procurements must take into account the requirements of DoD Directive 4100.35 which emphasizes the importance of considering, estimating, and evaluating the life

cycle cost implications of an acquisition. The problem of establishing a fair price for contractor warranty exposure is resolved by the pressures of competition when it is present and the contractor receiving the award is free to make investments in reliability improvement as necessary to maximize profit or minimize losses. When competition does not exist reliance on a life cycle cost curve such as Figure 1c must be evaluated. A worst case analysis in this instance will evaluate the lower bound of the cost curve against the contractor proposal of cost and reliability. If the contractor proposal is below the lower bound of the cost curve the decision to use RIW is valid. If the proposal is above the upper bound RIW should not be considered. The cases in which the sole source proposal falls within the band of uncertainty concerning costs, a qualitative evaluation must be made of the incommensurable factors.

Some relevant data has come out of the RIW programs and other cost studies to date in DoD. For example, it is estimated that a RIW contract increases the annual cost to the buyer by 6% to 9% of the unit production price. Experience on inertial navigation equipments in DoD indicates that 83% to 92% of the maintenance cost of these systems is incurred at depot repair facilities and that the annual direct cost at the depot is 13% to 18% of the system acquisition cost. The investment cost in maintenance handbooks, intermediate level test equipment, and intermediate and depot level spare parts and sub-assemblies plus maintenance training for one

year for the AWG-10 missile control system has been established at approximately 22% of the acquisition cost of the 430 unit AWG-10 inventory. The direct ten-year ownership cost for all avionics equipments has been estimated at 3.4 to 4.3 times the equipment cost. That value placed on the cost of ownership is exclusive of all indirect costs which are difficult to accumulate [Ref. 7]. The economic value of a RIW can be explained in terms of costs avoided but the magnitude of those costs can only be estimated in most instances. The development of cost estimating relationships (CER's) for such categories as development, production, publications, training, modification, and maintenance has allowed some preliminary evaluation of shipboard installations [Ref. 8]. Further work must be done in the development of meaningful CER's in order to make economic evaluation of RIW's a more exact science. Where cost data is extremely uncertain protection of buyer and seller interests may only be achieved by postponing the decision on procurement technique until the risks involved are defined to each party's mutual satisfaction.

IV. HISTORICAL APPLICATIONS

A. LEAR SIEGLER GYRO

The first attempt to utilize an express warranty of the RIW type in DoD procurement was for the MD-1 vertical gyroscope used extensively by the Air Force in the 1960's. Based on the Air Force's concern with real costs in procurement over the life of an equipment, the Instrument Division of Lear Siegler (LSI) submitted an unsolicited proposal for a Failure Free Warranty of the gyro in 1964 which would incorporate guaranteed operational performance, turn-around time, and reliability improvement. The warranty called for repair or replacement of any warranted gyro for a period of five years or 5,000 hours of operation, whichever comes sooner [Ref. 9, p. 24].

The Air Force refused the proposal and it was not until 1968 that the Navy entered into the first military RIW contract. This contract was again with Lear Siegler and it was for repair of the AJB-3 gyro used in the A-4 and F-4 aircraft. Prior to the award to LSI the Navy was experiencing maintenance-overhaul costs of $3.44 per operating hour and an operational MTBF of 400 hours. At the end of the five year contract the cost of repair was reduced to $2.08 per hour and the MTBF was improved to 531 hours [Ref. 10, p. 40]. Lear Siegler has a similar contract with the Air Force for gyros used in the F-111 aircraft. In this case, a 3000 hour or five year warranty is in effect. The unit production

cost is $6040 and the warranty cost is $2200 which represents about a 7% annual cost for repair. The current MTBF is 1214 hours, as compared with an estimated 749 hour MTBF for a competing unit not under warranty [Ref. 11, p. 623].

B. OTHER DOD EXAMPLES

Further examples of the use of Reliability Improvement Warranties in the acquisition of Government Furnished Equipment and spares have been documented in References 12 and 13. Until recently, however, there has been no attempt to extend the application of RIW to an entire system. The Naval Electronics System Command is presently pursuing the development of a new electronics warfare suite for shipboard installation, and the support of the deployed system may be on a RIW basis. The Air Force ARN-XXX TACAN program is nearing production award and the competitors for this contract have been aware of the RIW option throughout development. The warranty package to be included in this contract is quite extensive and will be discussed in a later section.

The requirements of all RIW's to date in DoD have included provisions for a smooth transition of the equipment from contractor support to the buyer's organic support system. These provisions include special tooling, technical data, training, field support and data accumulation and reporting. In most instances the supplier has delivered these items as not separately priced either during the performance of the contract or at termination. The degree of

data collection and reporting has generally been extensive not only for the buyer's benefit, but because the supplier uses the data during contract performance to make decisions concerning failure analysis of the entire population of equipments or on individual equipments by serial number. In some instances intermediate or depot level test equipment has been delivered. The transition of a proven design with all equipments in one configuration along with documentation on spare parts provisioning requirements is viewed as a factor militating in favor of the RIW concept.

C. AIRLINE INDUSTRY EXPERIENCE

A study of the experience the airline industry has had with RIW provides some historical perspective to the forthcoming discussion of DoD procurement and RIW. Standards for electronic equipment and systems and powerplant equipment have allowed the industry to specify form-fit-function types of requirements to be satisfied by suppliers. These standards (known as ARINC Characteristics) define the electrical, mechanical, and environmental interfaces to be encountered by a component and leave the design of it up to the suppliers [Ref. 14, p. 7]. Standardization of the task to be accomplished by a component throughout the industry allows equipment manufacturers to compete on an equal basis so long as the equipment is certified by the FAA. The unique feature of this type of specification is that details of construction, cost, or reliability are never explicitly spelled out. The competitive market place is relied upon to determine

these factors. If insufficient competition is present to ensure a reasonable minimum reliability will be achieved, an MTBF guarantee is included.

A sharp contrast in the operating environments of commercial and military aviation should be noted, but in the comparative studies done to date, the airlines have achieved higher MTBF rates for similar equipment which are also in military use [Ref. 15]. The extensive use of warranties by the airlines in procurement of avionics and engines exerts a positive influence on initial reliability achievements and on reliability growth. The range of annual cost of warranties for commercial airlines has been 4% to 10% of the unit acquisition cost.

The airline industry has established four basic types of warranties which are set forth in the <u>World Airline Suppliers' Guide</u>. The first type is a standard or failure free warranty which provides repair or replacement at supplier expense for a specified number of operating hours or calendar time. The second type is an ultimate life warranty which is applied to major structural components and extends beyond the limits of the two or three year failure free warranty but claims are usually adjusted on a pro-rated basis. Reliability guarantees are established to provide minimum MTBF rates and if not achieved, the supplier provides additional spare parts support or no cost modifications to the equipment to achieve the stated MTBF. The fourth type of warranty is a maximum parts cost guarantee which is used to

establish a maximum materials cost per flying hour for maintaining, modifying, repairing, and overhauling an equipment. Categories of equipments placed under this type of warranty include tires and brakes and the guarantee periods typically are ten years in duration. The standard or failure free warranty is most universal, although all four types are employed. Current practice is to include MTBF guarantees as well, although there is a trend towards replacing this with a MTBUR (mean time between unscheduled removal) guarantee. The major provisions of an airline warranty were presented by George Hiller of Pan American World Airways as follows: [Ref. 10, Section E]

(1) Establish a calendar time period and maximum operating hour limit for the component or system.

(2) Determine the responsibility for transportation costs of failed and repaired assemblies.

(3) Establish provisions for repair by the user and how these repairs will affect contractor payment.

(4) Set an equipment turnaround time and the penalties to be paid by the supplier.

(5) Establish MTBF guarantee.

(6) Define preventive maintenance requirements to be accomplished by the user.

(7) Provide for a maintenance cost guarantee which must be met by the supplier.

(8) Establish the requirements for manual, publications, and technical assistance.

(9) Establish equipment availability requirement and what steps the supplier must take to guarantee it.

Many of these provisions employed by the airlines have been incorporated in the application and evaluation criteria

to be discussed in the next section. Comments on the significance of these and other provisions will be presented later.

V. EXISTING APPLICATION CRITERIA

The technique suggested here may be used as a guideline for the buyer to be alert to the fact that consideration of warranty use is in order. The sequence of questions that the buyer must answer should lead to a preliminary decision of whether or not to explore the possibility of using RIW with prospective suppliers. The starting point for this analysis technique presupposes that a firm grasp of the MTBF requirement is at hand.

A. ARINC CRITERIA

The criteria developed by ARINC Research Corporation (see Appendix B) for the Rome Air Development Center is discussed in Reference 17 and was presented at the Joint Logistic Commanders Electronic System Reliability Workshop in January 1975. Some of the factors in the criteria are considered more important than others and therefore they are ranked according to the following classes:

1. Major: failure to meet the stated criterion could be grounds for not using warranty.

2. Secondary: failure to meet the stated criterion will generally not be sufficient basis for rejecting warranty but a combination of such events could be.

3. Minor: failure to meet these criterion is generally not considered serious but may require special considerations in structuring the warranty contract or administrative procedures.

Three broad areas of consideration have been found in the criteria. They are: procurement factors, equipment

characteristics, and application factors. Each area is considered equally important with respect to accepting or rejecting the use of warranty.

It is important to note that the warranty selection criteria presented should be used as a qualitative instrument for the measurement of systems as potential candidates for RIW usage. The decision to include a warranty clause in a procurement contract should not be made lightly since a proper approach involves a great deal of effort in structuring effective procurement, administrative and logistic provisions. The effort in preparing a response to the invitation for bids can be a costly exercise by the contractor and should not be imposed without a reasonable certainty that RIW will be employed.

An economic analysis of the potential of warranty support cannot be made until warranty price and implementation proposals are received from the bidding contractor. Exercise of a warranty life cycle model such as the one described in References 17 and 18 can provide a quantitative assessment of the warranty alternatives. Although data element requirements for this and similar models cannot be defined as point estimates, a range of values for speculative costs can be used to perform sensitivity analysis with the model.

B. DOD GUIDANCE

Direction from DoD in the use of RIW has come recently from the Offices of the Assistant Secretary of Defense (Installations and Logistics) and the Director of Defense Research and Engineering. Interest in RIW at the OSD level has prompted the initiation of test programs to determine whether potential economic reliability benefits do, in fact, result from the use of RIW. The Services have been requested to undertake trial use of RIW's in a number of electronic system/equipment programs. The focal point of these trial programs will be in the Office of the Assistant Secretary (I&L) with Donald F. Spencer who is the chairman of the Reliability Improvement Warranty Committee [Ref. 19, p. A-14].

The guidelines set forth in the joint memorandum issued by ASD (I&L) and DDR&E are similar to those published by the Air Force in July 1974 in its <u>Interim Guidelines Reliability Improvement Warranty (RIW)</u>. The application criteria established by both of these documents stress the importance of making the decision to use RIW as early as possible in the system life cycle, so that prospective contractors may make design trade-offs. The following criteria is presented from the Air Force interim guidelines and significant agreement can be seen with the criteria offered by ARINC previously.

1. A warranty can be obtained at a price commensurate with the contemplated value of the warranty work to be accomplished with consideration being given to the contractually specified R&M requirements.

2. Moderate to high initial support costs are involved.

3. The equipment is readily transportable to permit return to the vendor's plant or, alternatively, the equipment is one for which a contractor can provide field service.

4. The equipment is generally self-contained, is generally immune from failures induced by outside units, and has readily identifiable failure characteristics.

5. The equipment application in terms of expected operating time and the use of environment are known.

6. The equipment is susceptible to being contracted for on a fixed price basis, with competition on the basis for form, fit and function stimulated to the extent practicable.

7. The contract can be structured to provide a warranty period of from 3-5 years. This should allow the contractor sufficient time to identify and analyze failures in order to permit reliability and maintainability improvements.

8. The equipment has a potential for both reliability growth and reduction in repair costs.

9. Potential contractors indicate a cooperative attitude toward acceptance of a RIW provision and evaluation of its effectiveness.

10. A sufficient quantity of the equipment is to be procured to make the RIW cost effective.

11. The equipment is of a configuration that discourages unauthorized field repair, preferably sealed and capable of containing an Elapsed Time Indicator (ETI) or some other means of usage indication.

12. There is a reasonable degree of assurance that there will be a high utilization of the equipment.

13. The equipment is one that permits the contractor to effect no-cost ECPs subsequent to the Government's approval.

14. Failure data and the intended operational use data can be furnished the contractor for the proposed contractual period and updated periodically during the term of the contract.

The question of funding is addressed by OSD as follows:

In the past, different points of view have been expressed regarding the funding of RIWs. Lack of clear guidance in this area has caused difficulties in the use of this contractual technique. In order to provide clarification regarding the types of funds to be used for procurements incorporating RIW, the funding policy guidelines have been authorized for use by OASD (Comptroller) and Office of Assistant General Counsel (Financial Management). These funding guidelines should permit the more effective utilization of RIWs.

1. RIWs shall be funded from the same appropriation as the acquisition or overhead warranted (i.e., the warranty shall be paid from the procurement, operation and maintenance, or RDT&E appropriation of the service or agency concerned depending on from which of the said appropriations the acquisition or overhaul is funded). The RIW cost is part of the fixed contract price, and payment to the warrantor for the RIW portion shall not be made in a manner different than payment under the remaining portion of the contract, except that, payment for the RIW may be delayed until delivery or relinquishment of control of the item by the warrantor.

2. In order to maintain the important distinction between a RIW and a service contract covering normal, periodic maintenance, the following requirements must be satisfied:

A. The RIW shall be included in a fixed price contract for the acquisition or overhaul of an item or items.

B. The warranty period on each item shall begin after manufacture or overhaul, upon delivery or relinquishment of control of the item by the warrantor.

C. The RIW shall require the warrantor to repair or replace the warranted item upon failure.

D. The RIW shall not include requirements for the warrantor to provide normal upkeep, cleaning, adjusting, regulating or other periodic maintenance which would be required without respect to failure.

E. The RIW shall exclude components of the warranted item which under normal circumstances will require replacement before the expiration of the warranty (such as filters, lightbulbs, etc.). Such items may be provided for by separate provisions of the contract consistent with current laws and regulations, but they shall not be included in the RIW provision.

Although it is not possible to write one RIW clause for inclusion in a contract which is to use this warranty provision, there are some essential elements which normally should be considered. In the statement of the contractor warranty the following elements should be explicitly detailed:

1. State the duration that the warranty will be in effect, expressed in operating hours/cycles and calendar time.

2. State the primary objective of the warranty which normally will express a desire to motivate the contractor to design and produce equipment which is more reliable and less costly to repair than at present. If a guaranteed MTBF is required it should be clearly set forth.

3. State what constitutes a failure which will require the contractor to repair or replace the failed item.

4. State what conditions and actions associated with repairs are specifically excluded under the warranty.

5. State the requirements for paying shipping costs of failed units to and from the contractor's facility.

6. Indicate a separate price for the warranty coverage and for the basic unit procured in order to make it possible to determine the cost of the RIW.

Contractor obligations in performance of the RIW contract should also be expressed and include the following:

1. Require the contractor to mark all warranted items with the information necessary to make the item recognizable as a warranted part, the warranty period and the actions to take if the unit fails during the warranty period.

2. State the required turnaround time and contractual adjustments or other considerations to be expected if the contractor exceeds the TAT.

3. State the data requirements, both details to be reported and frequency.

Additional elements to be included in the RIW clase include the following items:

1. Indicate which party is to provide shipping containers if required.

2. State procedures for submittal of contractor initiated no-cost ECP's.

3. State the extent of inspection of failed and/or repaired units by both parties.

4. Indicate disposition procedures to be followed for units beyond economical repair and the disposition of the unused portion of the warranty for any unit subjected to an excluded failure or that is declared lost.

5. Indicate the requirement for both parties to notify each other, within a specified time, of any deficiency discovered in a unit.

6. State whether or not the contractor will be compensated for the cost of testing items for which no discrepancy is found.

7. Indicate the circumstances, if any, under which the buyer is authorized to make adjustments to units under warranty.

8. State the data requirements to be provided by the buyer on operation and maintenance of the system.

The extensive list of restrictions on the use of RIW may at first appear to all but eliminate the use of this mechanism in the acquisition process. The extent of the guidance provided is not meant to prohibit the use of RIW but rather is presented to make visible the possible pitfalls which could occur. There are some considerations to be made outside the application criteria and guidance offered by DoD which lend a touch of reality to the RIW concept.

First, the problem of sophistication of present weapon systems adds an increased burden of retention of qualified technical personnel. In an environment which has historically not been conducive to career technicians the need for simplified modular replacement of failed assemblies which have built-in test equipment is great. With personnel costs rising rapidly in the face of a shrinking defense budget there is an urgent need to reduce the estimated 27% of the Armed Services presently engaged in maintenance functions.

Second, the cost certainty provided by the RIW should be given some weight in the decision of whether to use it. Present economic uncertainties have caused many programs to suffer greatly at the hands of inflation even prior to reaching the stage of budgetary analysis. The rearrangement and smoothing effect of the buyer's cost flow can be considered another point in favor of the RIW.

Third, the awareness by qualified suppliers that a stable long-term relationship is established with the buyer in a RIW contract will make competition keen. Those suppliers having RIW contracts at present speak highly of the concept for at least two reasons. There is freedom to make decisions about the equipment design and limited outside influence on the contractor's operation. But uppermost in the contractor's mind is the thought that there is freedom to make a reasonable profit by engaging whatever resources are available.

Fourth, the incorporation of RIW in a contract does not preclude gaming on the part of the supplier. For example, if the average operating period of the equipment under RIW is a sufficiently large multiple of the guaranteed MTBF, it could be possible for an enterprising supplier to put a small quantity of very reliable components into service and thereby skew the distribution of failures while maintaining the desired mean. To guard against this possibility it is conceivable to construct the MTBF guarantee with a guaranteed distribution of times to failure about the mean. Experience to date has shown that the average equipment operating hours in a RIW contract has been two to four times the predicted or guaranteed MTBF, and this situation has essentially eliminated this type of gaming.

VI. ARN-XXX A CASE STUDY

By combining the ARINC developed criteria and DoD guidance a reasonably composite set of guidelines can be structured for use by the program or acquisition manager for testing the viability of RIW in a particular program. As an example of the application of these guidelines the recent experience in the Air Force ARN-XXX TACAN program will be discussed. A complete summary of this program authorized by Harold S. Balaban can be found in Proceedings 1975 Annual Reliability and Maintainability Symposium.

The Air Force's desire to acquire a highly reliable short-range navigation system to replace the obsolescent tube-type designs developed in the 1950's led to the 1971 feasibility study by two contractors (Collins Radio Company and ITT Avionics Division). The outcome of the study was the conclusion that a new system could be developed at or below the Air Force price ceiling of $10,000 per set and would meet the desired specifications. In mid-1972 a request for proposal (RFP) was issued which called for a solid-state system meeting new FAA requirements for an increased number of channels, having built-in test equipment (BITE) and using a digital output. The maintenance concept to be employed was discard at failure. The RFP further called for the cost and MTBF values of the feasibility study which represented a 2-to-1 cost improvement over prior TACAN systems

and a 10-to-1 improvement in reliability. The test program called for in-plant, system flight tests, prototype environmental tests, maintainability demonstration to MIL-STD-471, and a reliability demonstration to MIL-STD-781 (Test Plan III, Test level F, θ_0= 1000 hours, θ_1= 500 hours). The desire to encourage competition throughout the acquisition cycle led to the inclusion of a provision for set interchangeability through standardized mounting and pin designations.

Two alternative approaches for reliability and life cycle cost control for the production contract were stated in the RFP. The contractors were required to provide the following parameters which were to be used in a life cycle cost equation: unit production price, MTBF, MTTR, training and documentation costs, and ratio of base and depot repair. After a two year field monitoring program, a 10-year life cycle cost target will then be established against which the contractors will be measured to determine bonus/penalty amounts. This first approach represented costs to be incurred by the Air Force based on in-house support of the system.

The alternative approach required the contractor to provide a RIW for 48 months starting on 31 December of the year in which the Air Force accepted delivery. It incorporated an MTBF guarantee with reliability improvement milestones to be met throughout the contract.

Five companies responded to the RFP, with Collins Radio Corporation and General Dynamics Electronics being selected

in April 1973 to compete in dual development for the production award. Through the development phase constant contact was maintained between government and contractor representatives to ensure that fair and complete information was being exchanged without compromising the integrity of the competition. The contractors are at present responding to the production RFP which was developed with many of the contractors' ideas incorporated.

The conformance of the ARN-XXX program to the RIW application criteria proposed by ARINC and the guidance suggested by DoD is represented in Figure 6.

The extent to which the two marginal cases will impact on the warranty price is uncertain but an attempt was made in the contract to reduce both government and contractor risk in those areas. An operating hour adjustment provision called for a contract price adjustment formula to be invoked if the 68-hour-per-month standard was deviated from by more than 5%. The marginal conformance with the R&M estimation criterion was discounted because at the time of preparation of the production proposals both contractors had performed qualification, reliability/maintainability demonstration, and some flight tests on prototypes. Also the designs employed standard types of functions all of which were in the state-of-the-art.

The experience gained from this and other recent procurements where RIW may be applicable have resulted in at least four general policies for obtaining the best possible warranty

Figure 6

APPLICABILITY OF THE ARN-XXX
TO A WARRANTY PROCUREMENT

Applicability Criterion	Degree of ARN-XXX Conformance: Satisfactory	Marginal	Unsatisfactory
Equipment Factors			
Self-contained, sealed units	X		
Units not highly dependent on outside units to perform major functions	X		
Sufficient development for R&M estimation		X	
Elapsed time indicator instrumentation	X		
Maintenance and Support Factors			
Units should be field testable	X		
Moderate to high initial support cost under organic maintenance	X		
Readily transportable units	X		
Operational Factors			
Unit application known	X		
Expected operating time known		X	
Large population and utilization rate	X		
Procurement Factors			
Warranty provisions in development contract	X		
Competitive fixed-price production award	X		
Multi-year funding available for warranty costs	X		

Source: H. S. Balaban

clause. These policies constitute good management practices in their own right and if consideration of a RIW in an acquisition does nothing more than promote these functions then there will be implied improvement in the acquisition process.

In the ARN-XXX program free interchange of ideas on warranty was enhanced by holding separate meetings with the two contractors about five months after the award of the development contract. The Navy experience has been somewhat the same with the shipboard electronics warfare suite developed by the Naval Electronics Systems Command which was previously mentioned. Continual interface with the contractors during all stages of the acquisition concerning the provisions of the warranty will ensure both complete understanding of its significance and a realistic pricing of the warranty by the contractor. Care must be exercised to control the exchange of data between buyer and prospective seller to guard against giving one contractor a competitive edge.

The second policy adopted to obtain the best possible warranty was the promotion of data interchange between Services where experience had been gained in warranty procurement. This policy is relevant in all warranty situations to discover the advances which have taken place in other agencies and for one reason or another have gone unpublished.

The third general policy concerns the experiences of the airlines in warranty contracting which, in the ARN-XXX program, led to the inclusion of the MTBF guarantee provision. Other experiences which could prove useful are the form,

fit and function specifications that provide the basis for airline avionics procurements. Relaxation of stringent specifications and standards which in many cases are outdated and unrealistic may allow procurement of commercial, off-the-shelf items in many instances where otherwise a specifically designed and expensive piece of equipment would be procured.

The final general policy could be termed Integrated Logistic Support Management, and although this function is the responsibility of each program/acquisition manager in both government and commercial acquisition programs, it is occasionally found to be lacking. In the case of the ARN-XXX the Air Force found that it was able to uncover, discuss, and prevent problems from occurring further downstream in its program by talking with the users and the support activities early in the development stages of the acquisition.

VII. RECOMMENDATIONS AND CONCLUSIONS

Throughout the research effort in preparation for this thesis two significant problem areas became evident. The first area concerns the requirements determination process. Additional emphasis on the subject of arbitrary reliability requirements should be made in an attempt to make operational requirements realistic in the light of existing and foreseeable technological capabilities.

The second area of concern which was voiced by industry and military participants in warranty procurements concerns the formation of a warranty evaluation center. The approach taken to incorporate warranties into the acquisition of major weapon systems and subsystems to date has been fragmented and generally uncoordinated. The establishment of an evaluation center either within DoD or as a contracted support function would add greatly to the overall procurement wisdom and could serve as a data collection activity, evaluation facility, and point of assistance in formulating contract warranty provisions.

As stated at the outset there exists an intrinsic goal conflict in the buyer/seller relationship which heretofore has remained unresolved by conventional contracting techniques. The incorporation of Reliability Improvement Warranties in the acquisition of systems or equipments which conform to the criteria presented will not only provide the reliability desired by the operators but will establish for

the buyer reasonable cost certainty for the initial deployment period of the system. The problem of retention of personnel with technical skills required to perform maintenance on complex equipments may require RIW support in the future.

Caution, however, must be exercised in the decision to invoke a RIW in the production contract. The long term relationship established between the buyer and seller can be an overwhelming liability instead of the valuable asset for which it was intended. A greater degree of business management sense must be exercised in evaluating the contractor's long term capabilities to meet the contractual demands of the RIW. It is not intended that RIW become the new "buzzword" in weapon system acquisition, for nothing could be less conducive to a reasonable and considered application of warranties. As in all firm-fixed price contracts the total cost risk belongs to the seller, but the ultimate program risk remains with the buyer, and in the DoD environment the cost of program failure may be inestimable.

APPENDIX A

<u>ASPR 1-324.3(b)</u> In deciding whether to use a warranty clause, at least the following factors shall be considered:

(i) nature of the item and its end use;

(ii) cost of the warranty and degree of price competition as it may affect this cost;

(iii) criticality of meeting specifications;

(iv) damages to the Government that might be expected to arise in the event of defective performance;

(v) cost of correction or replacement, either by the contractor or another source, in the absence of a warranty;

(vi) administration cost and difficulty of enforcing the warranty;

(vii) ability to take advantage of the warranty, as conditioned by storage, time, distance of the using agency from the source, or other factors;

(viii) operation of the warranty as a deterrent against deficiencies;

(ix) the extent to which Government acceptance is to be based upon contractor inspection or quality control;

(x) whether because of the nature of the items the Government inspection system would not be likely to provide adequate protection without a warranty;

(xi) whether the contractor's present quality program is reliable enough to provide adequate protection without a warranty, or, if not, whether a warranty would cause the contractor to institute an effective and reliable quality program;

(xii) reliance on "brand name" integrity;

(xiii) whether a warranty is regularly given for a commercial component of a more complex end item;

(xiv) criticality of item for protection of personnel or property, e.g., for safety in flight;

(xv) the stage of development of the item and the state of the art; and

(xvi) customary trade practices.

APPENDIX B

SELECTION CRITERIA

CRITERIA	RATIONALE	IMPORTANCE*
Procurement Factors		
P.1 - The procurement is to be on a fixed-price basis.	The provisions of ASPR provide that contractor warranty expenses are admissable under a cost-type contract.	1
P.2 - Multi-year funding for warranty services are available.	To realize the full potential of warranty, the warranty period must be of sufficient duration to provide the contractor strong incentive to achieve and maintain high reliability. Sufficient funds to cover such multi-year services must be budgeted.	1
P.3 - The procurement is competitive.	In a sense, a warranty maintenance concept is always competing with organic maintenance. However, competition among contractors will tend to provide more realistic warranty pricing which, for large procurements, can involve large sums of money.	2
P.4 - Potential contractors have a cooperative attitude toward acceptance of a warranty.	Successful warranty application heavily depends on contractor motivation and performance. Reluctance to accept a warranty provision may be due to lack of understanding of warranty terms and conditions.	2

* 1 = Major
2 = Secondary
3 = Minor

CRITERIA	RATIONALE	IMPORTANCE*
P.5 - Potential contractors have proven capability and experience in providing warranty-type services.	Experience and capability in maintaining military equipment will provide contractors a good basis for pricing warranty realistically and for successfully performing warranty tasks.	2
P.6 - The procurement quantity is large enough to make warranty economically attractive.	A significant portion of warranty costs may be essentially fixed, e.g. facilities and test equipment. Unless the procurement size is large, such costs may tend to drive the warranty price per delivered unit to an unacceptably high level.	2
P.7 - Analysis of warranty price versus organic repair costs is possible.	If warranty is an option, the final decision will be made when contractor warranty price bids are received. Evaluation of such bids is best made when compared to equivalent costs under organic maintenance.	3
P.8 - An escalation clause is included in the contract which is applicable to warranty costs.	Unless such a clause is included, contractors may tend to price-in an abnormally high price-risk factor to account for price level uncertainties.	3
P.9 - The contract can be structured to provide for incremental payments for warranty services.	From a financial as well as control viewpoint, such a payment procedure appears to be a logical approach.	3

CRITERIA	RATIONALE	IMPORTANCE*
Equipment Factors		
E.1 - Equipment maturity is at an appropriate level.	Warranty should not be used for items which are considered to be developmental. Conversely, for very mature items, warranty may not offer proper incentive. Warranty is intended for proven designs (non-experimental) which are entering full scale production. Through warranty, feedback is provided to the contractor to achieve stated reliability levels through an improvement or growth process. A very mature design, which has undergone such growth, may not be a candidate for cost effective warranty application.	1
E.2 - Control of unauthorized maintenance can be exercised.	Unauthorized maintenance of a warranted item is a normal exclusion to a reliability improvement warranty. Items whose construction precludes the installation of seals or other control mechanism are considered to be poor candidates for warranty unless careful maintenance technician discipline can be exercised.	1
E.3 - Unit is field testable.	Since compliance with most warranties will require the failed unit to be returned to the vendor, it is important that the unit be field testable to determine if it is in a go or no-go state. Lack of field testability can greatly increase cost of support due to added pipeline spares required plus the added expense of testing the good item by the contractor.	1

* 1 = Major
2 = Secondary
3 = Minor

CRITERIA	RATIONALE	IMPORTANCE*
E.4 - Unit can be properly marked or labeled to signify existence of warranty coverage.	The most effective manner in which to communicate the existence of warranty coverage is by suitable marking of the item itself. Items which due to their physical size or the nature of their external surface preclude such marking are thus not considered good candidates for warranty coverage.	1
E.5 - Unit should be susceptible to Class I and II changes for R&M improvement.	A primary objective of warranty is reliability and maintainability growth. The contractor should be permitted to implement no-cost ECP's subject to timely government review.	2
E.6 - Unit is reasonably self-contained.	If the performance of an item is highly dependent upon the performance of auxiliary equipment, it may be difficult to determine which equipment is at fault during a system failure and frequent disputes may arise. Ideally, warranties should be supplied by the system integrator or at least flowed down in a consistent manner to the item suppliers.	2
E.7 - Unit can be readily transported to the contractor's facilities.	The contractor's most cost effective method of providing warranty service is to make use of his centralized facilities. It may, however, in the case of large ground installations, be cost effective for the contractor to establish on-site warranty service.	2

CRITERIA	RATIONALE	IMPORTANCE*
E.8 - Unit should have high level of ruggedization.	Delicate units highly subject to failure from handling and shipping may lead to an unacceptably high rate of occurrence of warranty exclusions for mistreatment or abuse. In such cases, special shipping containers may be required.	2
E.9 - Unit maintenance is highly complex.	If the units' maintenance requirements involve highly trained personnel and/or test equipment which the government cannot be certain of acquiring initially, warranty may be a better contracting form than a time and materials maintenance contract.	3
E.10 - An elapsed time indicator can be installed on the equipment.	ETI's permit accurate measurement of operating time thereby permitting more complete assessment of usage, failure rates and trends.	3

CRITERIA	RATIONALE	IMPORTANCE*
Application Factors A.1 - Use environment and operating time exposure are known or predictable.	In order for the contractor to effectively evaluate and price his warranty liability, information on the expected use environment and equipment operating time must be available to him. Such information is also required by the contracting agency in order to independently evaluate the warranty price. However, there is a method by which warranty price can be adjusted for variance in operating time from a "pricing standard."	1
A.2 - Equipment operational reliability and maintainability are predictable.	Estimating reliability is important for determining the expected number of failures and estimating maintainability is important for determining expected repair costs. Too much uncertainty in such estimation procedures may expose the contractor to undue risks.	1
A.3 - Equipment wartime criticality is not of the highest level.	Any reduced self-sufficiency arising from warranty maintenance must be tolerable in a wartime situation. Even though the government has the authority to request expanded services, timely planning for implementing wartime provisions and/or organic maintenance takeover must be made.	1

* 1 = Major
2 = Secondary
3 = Minor

CRITERIA	RATIONALE	IMPORTANCE*
A.4 - Equipment has high operational utilization rate.	High utilization will permit early surfacing of deficiencies, economic diffusion of fixed warranty costs and more precise estimates of R&M parameters. Equipments which remain dormant for long periods and have limited shelf life may not receive sufficient exposure to make warranty worthwhile.	2
A.5 - Warranty administration can be efficiently accomplished.	The success of a warranty program requires that careful attention be given to the plan for warranty administration. The administration plan must include identification of material flow paths, cognizant agency responsibilities and procedures along with generation of requisite data to implement warranty terms and conditions. Since DCAS will ordinarily have heavy responsibilities for in-plant contractor performance, such involvement must be considered.	2
A.6 - Warranty may not be appropriate when the replication of an existing or desired government repair facility would not be cost effective.	If the provision of a contractor warranty repair operation entails the establishment of costly maintenance facilities which are duplicative of current military facilities, the use of warranty would not be cost effective. Additionally, in the case where such facilities do not exist, the government may determine that it is in their best interest to acquire this capability rather than have the contractor provide it under a warranty arrangement.	2

CRITERIA	RATIONALE	IMPORTANCE*
A.7 - Unit reliability and usage levels are amenable to warranty maintenance.	Units which are highly reliable may not fail often enough to justify a warranty procurement, especially if the government already has repair capability. Similarly, if the unit reliability/operational usage level leads to a large number of failures, warranty support may be uneconomical due to the large number of spares required to maintain the pipeline to the contractor's plant as compared to the cost of on-site field repair.	2
A.8 - Detailed operational failure and usage information can be supplied to the contractor.	To achieve reliability growth as expeditiously as possible, pertinent failure and usage information should be supplied to the contractor to the extent possible.	3
A.9 - Bakcup warranty repair facilities are available.	In order to minimize the disrupting effects of strikes or natural disasters, it is advantageous to have a contractor who can maintain a backup facility remotely located from the main facility.	3

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